



Westinghouse Electric Company  
Nuclear Services  
P.O. Box 355  
Pittsburgh, Pennsylvania 15230-0355  
USA

U.S. Nuclear Regulatory Commission  
Document Control Desk  
Washington, DC 20555-0001

Direct tel: (412) 374-4643  
Direct fax: (412) 374-4011  
e-mail: greshaja@westinghouse.com

Our ref: LTR-NRC-04-63

Attn: J. S. Wermiel, Chief  
Reactor Systems Branch  
Division of Systems Safety and Analysis

October 29, 2004

Subject: "Response to NRC request for Additional Information #3 for Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™" (Proprietary/Non-Proprietary)

Dear Mr. Wermiel:

Enclosed is a copy of "Response to NRC request for Additional Information #3 for Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™" (Proprietary/Non-Proprietary).

Also enclosed is:

1. One (1) copy of the Application for Withholding, AW-04-1918 (Non-Proprietary) with Proprietary Information Notice.
2. One (1) copy of Affidavit (Non-Proprietary).

This submittal contains proprietary information of Westinghouse Electric Company LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

"ZIRLO™ trademark property of Westinghouse Electric Company LLC"

T007

Correspondence with respect to this affidavit or Application for Withholding should reference AW-04-1918 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

A handwritten signature in black ink, appearing to read "J. A. Gresham", written in a cursive style.

J. A. Gresham, Manager  
Regulatory Compliance and Plant Licensing

Attachments

cc: F. M. Akstulewicz/NRR  
P. Clifford/NRR  
W. A. Macon Jr./NRR  
E. S. Peyton/NRR



Westinghouse Electric Company  
Nuclear Services  
P.O. Box 355  
Pittsburgh, Pennsylvania 15230-0355  
USA

U.S. Nuclear Regulatory Commission  
Document Control Desk  
Washington, DC 20555-0001

Direct tel: (412) 374-4643  
Direct fax: (412) 374-4011  
e-mail: greshaja@westinghouse.com

Our ref: AW-04-1918

October 29, 2004

**APPLICATION FOR WITHHOLDING PROPRIETARY  
INFORMATION FROM PUBLIC DISCLOSURE**

Subject: "Response to NRC request for Additional Information #3 for Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™" (Proprietary)

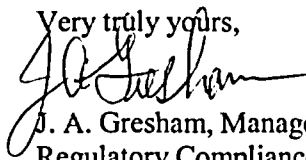
Reference: Letter from J. A. Gresham to J. S. Wermiel, LTR-NRC-04-63, dated October 29, 2004

The Application for Withholding is submitted by Westinghouse Electric Company LLC (Westinghouse), pursuant to the provisions of Paragraph (b) (1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-04-1918 accompanies this Application for Withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this Application for Withholding or the accompanying affidavit should reference AW-04-1918 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,  
  
J. A. Gresham, Manager  
Regulatory Compliance and Plant Licensing

Attachments

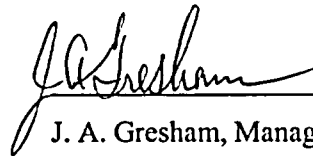
AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

SS

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:



J. A. Gresham, Manager

Regulatory Compliance and Plant Licensing

Sworn to and subscribed  
before me this 29<sup>th</sup> day  
of October, 2004



Notary Public

Notarial Seal  
Sharon L. Fiori, Notary Public  
Monroeville Boro, Allegheny County  
My Commission Expires January 29, 2007  
Member, Pennsylvania Association Of Notaries

- (1) I am Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.
- (2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.
- (3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.
- (4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
  - (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.
  - (ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

- (a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of

Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

- (b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.
- (c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.
- (d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.
- (e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.
- (f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

- (a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.
- (b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.
- (c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

- (d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.
  - (e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.
  - (f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.
- (iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.
- (iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.
- (v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in, "Response to NRC request for Additional Information #3 for Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™", (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-04-63) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with Westinghouse's requests for NRC approval of Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™.

This information is part of that which will enable Westinghouse to:

- (a) Obtain NRC approval of Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLOTM.
- (b) Assist customers to obtain license changes resulting from application of Optimized ZIRLOTM.

Further this information has substantial commercial value as follows:

- (a) Westinghouse plans to sell the use of the information to its customers for the purpose of meeting NRC requirements for licensing documentation.
- (b) Westinghouse can use this information to further enhance their licensing position with their competitors.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar materials and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

### Proprietary Information notice

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

## **COPYRIGHT NOTICE**

The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which are necessary for its internal use in connection with generic and plant-specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection notwithstanding. With respect to the non-proprietary versions of these reports, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

**Response to NRC Request for Additional Information #3 for  
Addendum 1 to WCAP-12610-P-A and CENPD-404-P-A Optimized ZIRLO™**

**RAI #3** Irradiation experience with Optimized ZIRLO™ is discussed in Section 3.5  
(a) In light of the limited database presented, justify the material properties up to 62,000 MWD/MTU.

**Response:**

Physical property data presented in this topical are summarized in Table 3.3-1. Various final anneal conditions were tested and presented in the topical for comparison as follows: Material Type A is nominal [ ]<sup>a,c</sup> Optimized ZIRLO [ ]<sup>a,c</sup>; Type B is nominal [ ]<sup>a,c</sup> Optimized ZIRLO [ ]<sup>a,c</sup>; Type C is standard ZIRLO [ ]<sup>a,c</sup> in the stress-relief anneal condition; and type D is Zircaloy-4 in the stress-relief anneal condition.

In the future when Westinghouse reports data to the NRC on the performance of Optimized ZIRLO LTAs we will include the final anneal condition of the material for information.

The starting unirradiated properties are affected by the final anneal and the properties are accounted for in the appropriate design models. For high temperature conditions, above 600° - 650° C, the microstructure is changed by recrystallization which erases the effects of the final anneal. Thus, the high temperature properties are not affected by the final anneal condition.

The characterization testing reported in the addendum demonstrates that standard ZIRLO material properties currently used in various models and methodologies are applicable to analyses of Optimized ZIRLO. The primary effect of a reduced tin level in Optimized ZIRLO is a minor reduction in the unirradiated mechanical strength and improvement in the corrosion resistance. Since the precipitate structure remains the same for Optimized ZIRLO, the past performance of Standard ZIRLO precipitate structure at high burn-ups also is applicable.

Likewise, with irradiation strengthening occurring early on in the first cycle of irradiation, the mechanical strength properties of Optimized ZIRLO performance will be the same as the current ZIRLO. Justification for this assessment comes from an examination of the metallurgical conditions that primarily leads to the observed lower un-irradiated Optimized ZIRLO strength and numerous published and internal Westinghouse irradiation data sets that support the assertion that the metallurgical differences are essentially erased by irradiation.

There are [ ]<sup>a,c</sup> differences between the Optimized and Standard ZIRLO. [ ]

] <sup>a,c</sup>

ZIRLO™ trademark property of Westinghouse Electric Company LLC.

[

]<sup>a,c</sup>

The effect of Sn will be discussed first, because it is directly supported by existing data. For these discussions, comparison of only the yield strength will be made for the sake of simplicity. The trends for ultimate strength follow those for yield strength, with the elongation and reduction of area having inverse relations with yield strength. The tensile data presented in the original Submittal were averaged, and the yield strengths of the Optimized and Standard ZIRLO at room temperature and 385°C are tabulated in Table 1.

Table 1 – A comparison of typical Optimized and Standard tin ZIRLO yield strengths.

	a,b,c
--	-------

The un-irradiated properties of the two variants of ZIRLO given in the original submittal shows a decrease of approximately [ ]<sup>a,c</sup> at room temperature and [ ]<sup>a,c</sup> at 385°C for the Optimized alloy compared to the Standard alloy. However, these differences include the effects of both the tin and the microstructure. When both alloys are in equivalent microstructures, such as SRA and RXA, the strengths are much closer together. Such data were created in the development programs for the cladding and thimble tubes. When both alloys were given the identical stress-relief-anneal-treatment, the RT yield stress of Optimized ZIRLO was [ ]<sup>a,c</sup>, slightly less than the [ ]<sup>a,c</sup> for the Standard ZIRLO tubing used in that development program, but within the variability of Standard ZIRLO and the same as the average yield stress used of the lot of Standard ZIRLO tubing given in the Submittal. Furthermore, when both standard and Optimized ZIRLO are fully re-crystallized the yield strengths of the two alloys are essentially identical. The data on the re-crystallized materials were

determined in the Thimble Tube Development Program and are given in the above table. These data strongly indicate that the effect of lowering the tin from [ ]<sup>a,c</sup> has only a very small effect, if any, on the yield stress of the Optimized ZIRLO alloy. The effect is estimated to be less than [ ]<sup>a,c</sup> at room temperature, and [ ]<sup>a,c</sup> at 316°C. The small impact of tin on the yield strength of irradiated material is also apparent in hot-cell measurements of conventional and low tin Zircaloy-4<sup>[11]</sup>, in which the low tin version of the alloy showed yield strength bounded by the scatter of the conventional tin Zircaloy-4 at a fluence around  $7 \times 10^{21} \text{ n/cm}^2$ . The same reference also showed irradiation strengthening to saturate at a low fluence of less than  $2 \times 10^{21} \text{ n/cm}^2$ . A plot of the data is shown in Figure 1.

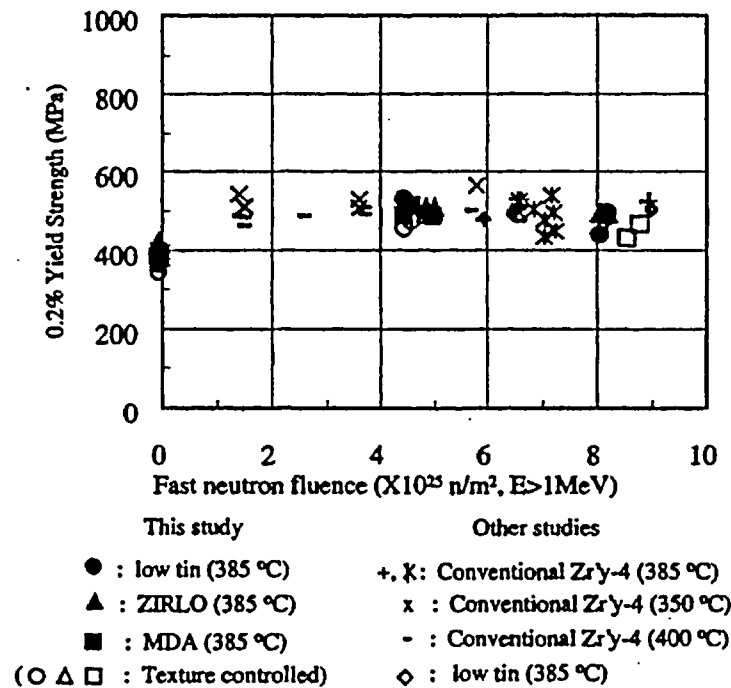


Figure 1 – Change of 0.2% yield strength by fluence<sup>[11]</sup>.

Therefore, it is the effect of the [ ]<sup>a,c</sup>

[ ]<sup>a,c</sup>. The basis for this is provided in Westinghouse hot-cell data and two publications<sup>[2&3]</sup> on the properties of the Zircaloy alloys. Information from hot-cell testing of irradiated ZIRLO thimble tubes and cladding confirms the effects of irradiation strengthening in reducing/negating the strength differences initially present in the starting un-irradiated material. Due to processing differences the standard ZIRLO thimble tubes have a lower un-irradiated strength, by approximately [ ]<sup>a,c</sup>, compared to un-irradiated fuel cladding. As shown in the data table included in the response to RAI#25, measured strength of cladding and thimble tubes show a significant difference in un-irradiated strength but upon irradiation the mechanical strength of both the thimble tube and the cladding are increased to similar levels. The difference in un-irradiated mechanical strengths between Standard and Optimized ZIRLO is much less than the corresponding difference between cladding and thimbles.

Bement<sup>121</sup> reported on the effect of irradiation on the mechanical behavior of Zircaloy-2 plate samples before irradiation and after irradiation at 280°C. Tensile testing was performed at room temperature and 300°C. Materials tested were as-recrystallized, 20% cold worked, and 40% cold worked. Review of the data show much greater irradiation hardening in the annealed material than in the cold worked materials, to the extent that the longitudinal yield stresses of all samples were nearly equivalent at fluences of  $1.5$  and  $2.5 \times 10^{21} \text{ n/cm}^2$ . Furthermore, the irradiated yield strengths at 300°C after  $2.5 \times 10^{21} \text{ n/cm}^2$  were somewhat less than those at  $1.5 \times 10^{21} \text{ n/cm}^2$ , suggesting that saturation damage had already been achieved by  $1.5 \times 10^{21} \text{ n/cm}^2$ . Some of the Bement data are shown in Figure 2 and re-plotted as a function of fluence in Figure 3. A quote from the abstract of the Bement paper is "At high neutron doses at 280°C, yield strength becomes nearly independent of cold work indicating that radiation-induced hardening overrides strain-induced hardening."

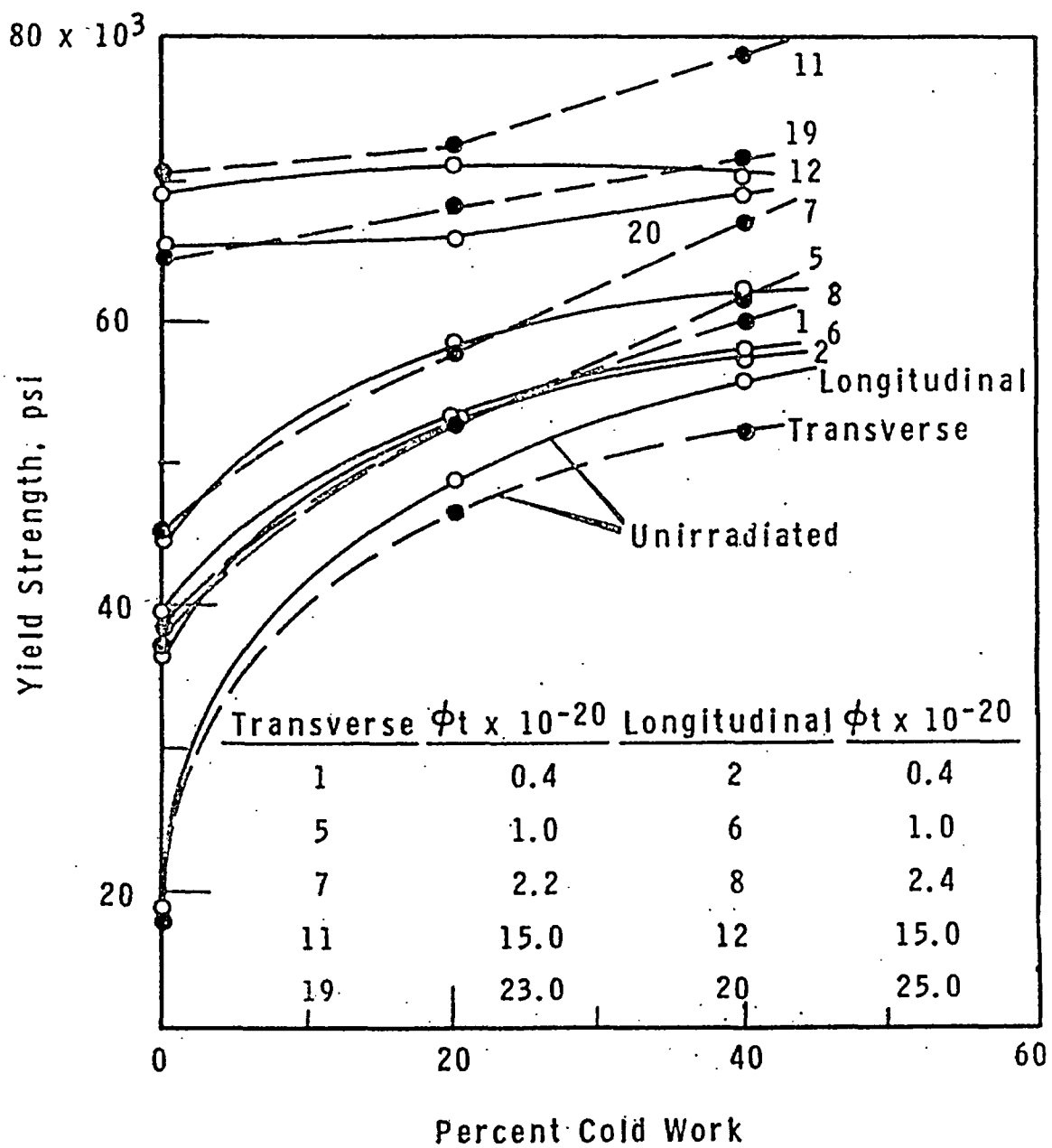


Figure 2 - The effects of cold Work on the 300°C Yield Strength of Zircaloy-2 both before and after irradiation at 280°C.<sup>[1]</sup>

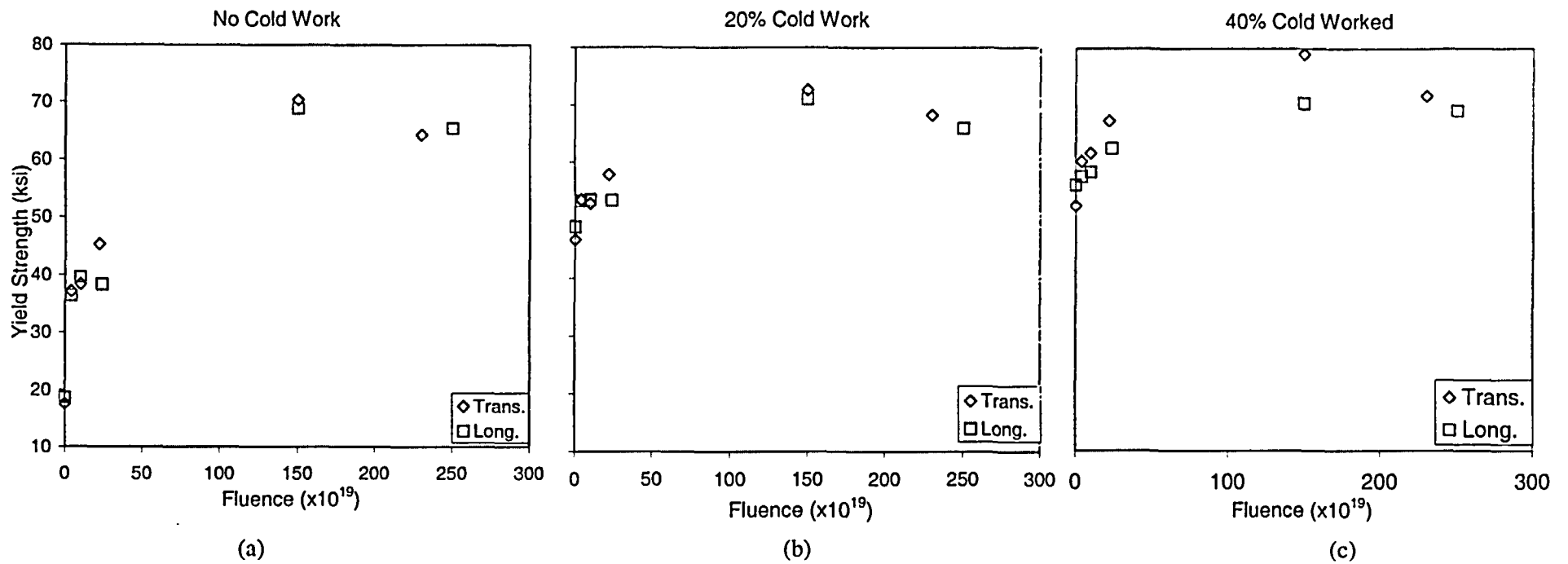


Figure 3 - Zircaloy-2 strip yield strength as a function of fluence (a) fully annealed, (b) 20% cold worked, and (c) 40% cold worked. Data re-plotted from Reference 2.

The Bement data and other data on the effect of irradiation on mechanical properties of Zircaloy-2 and -4 were reviewed by Salvaggio and documented along with new data in a Bettis Atomic Power Laboratory report edited by Woods<sup>[3]</sup>. It was concluded "...that the strength increment due to irradiation is less for cold-worked plate material than for annealed material and that at high exposure levels ( $2.5 \times 10^{21}$  nvt), little difference in yield strength exists among 0, 20, or 40% cold-worked material." Additional data from SRA tubing indicates that irradiation saturation of mechanical behavior may occur at as low  $5 \times 10^{20}$  n/cm<sup>2</sup>, as the properties at this fluence were essentially the same as those at  $5 \times 10^{21}$  n/cm<sup>2</sup>. This saturation of mechanical properties of SRA tubing at  $5 \times 10^{20}$  n/cm<sup>2</sup> is similar to the near saturation of the yield strength of annealed Zircaloy tubing at that fluence reported by Pettersson, et. Al.<sup>[4]</sup>, shown in Figure 4. It is noted that Pettersson did not fit his data to a saturation model, but rather expressed them in an exponential form.

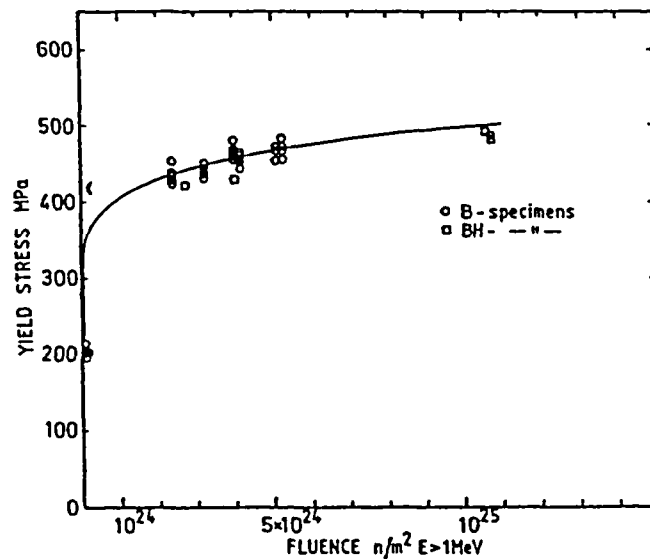


Figure 4 – Yield strength as a function of fluence for re-crystallized Zircaloy tubing<sup>[4]</sup>.

Another evidence of more rapid hardening in annealed versus cold-worked or SRA material is provided by Hardy<sup>[5]</sup>, although his fluences were too low for saturation. Hardy's annealed material, which was irradiated to  $2.0 \times 10^{20}$  n/cm<sup>2</sup>, displays about the same irradiation-induced increment of yield strength (Hardy's  $\sigma_r$ ) as does his cold-worked (CW) and CW+SRA materials, which were irradiated to  $2.7 \times 10^{20}$  and  $2.9 \times 10^{20}$  n/cm<sup>2</sup>. Thus, these CW and CW+SRA materials had fluences of 35 to 45% higher than did the annealed material. It is to be noted that the data for the annealed material is erroneously plotted in reference 5. The yield stress for these samples was incorrectly plotted at the higher fluence of  $2.9 \times 10^{20}$  n/cm<sup>2</sup>, instead of at the correct value of  $2.0 \times 10^{20}$  n/cm<sup>2</sup>. It is noted that the correct fluence was used in the NRC basis for response to the Westinghouse response to RAI #25.

While the bulk of the irradiated mechanical properties discussed thus far are based on Zircaloy-2 and Zircaloy-4, similar irradiated data on the Russian E635 in the literature - an alloy similar composition to ZIRLO, also showed full irradiation hardening at a fluence of around  $2.7 \times 10^{21}$  n/cm<sup>2</sup> with majority of the hardening occurring less than  $5 \times 10^{20}$  n/cm<sup>2</sup>.<sup>[6]</sup> A plot of their data is shown in Figure 5. A conversion factor of 0.27 was used to convert the neutron energy of  $\geq 0.5$  MeV to  $\geq 1$  MeV.

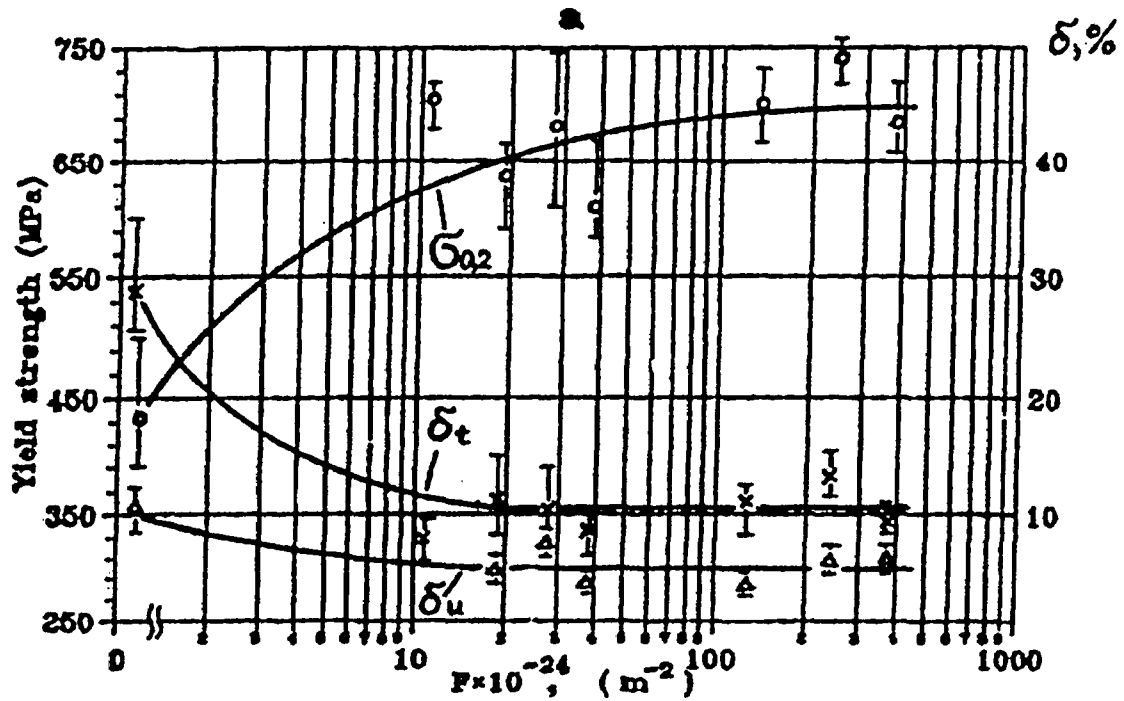


Figure 5 – E635 yield strength at 20°C plotted as a function of fluence ( $\geq 0.5$  MeV).

## Summary

[

] <sup>a,c</sup>.

In view of the new data presented and discussed, Westinghouse includes the following items in the design of Optimized ZIRLO cladding:

[

] <sup>a,c</sup>

[

]<sup>a,c</sup>

(3) As additional irradiation mechanical data is generated, the reductions in design strength levels for Optimized ZIRLO as addressed in (2) above will be evaluated and the design strength levels may be revised as justified by the generated data.

(4) For applications in beginning of life fuel rod design analyses that are sensitive to un-irradiated properties the un-irradiated mechanical properties will be used for Optimized ZIRLO fuel. For example un-irradiated properties will be used in evaluating early life limiting cases such as clad free standing.

## References

- [1] H. Uchida, K. Goto, R. Sabate, S. Abeta, T. Baba, E. De Matias, J.M. Alonso, "Segmented Fuel Irradiation Program Investigation on Advance Materials", Proceedings of the TopFuel '99 Conference, September 1999, Avignon Popes'Place France.
- [2] A.L. Bement, Jr., "Radiation Damage in Hexagonal Close-Packed Metals and Alloys," in *Symposium on Radiation Effects*, Asheville, NC, Sept. 1965, AIME Vol 37, American Institute of Mining Metallurgical, and Petroleum Engineers, Gordon and Breach, p671, 1967.
- [3] G. J. Salvaggio, "Effect of Irradiation on Mechanical Properties," in *Properties of Zircaloy-4 Tubing*, C. R. Woods, Ed., WAPD-TM-585, p 172, December 1966.
- [4] K. Pettersson, G. Vesterlund, and T. Andersson, "Effect of Irradiation on the Strength, Ductility, and Defect Sensitivity of Fully Recrystallized Zircaloy Tube," *Zirconium in the Nuclear Industry (Fourth Conference)*, ASTM STP 681, ASTM, p155, 1979.
- [5] D. Hardy, "The Effect of Neutron Irradiation on the Mechanical Properties of Zirconium Alloy Fuel Cladding in Uniaxial and Biaxial Tests," *Irradiation Effects on Structural Alloys for Nuclear Reactor Applications*, ASTM STP 484, ASTM, p215, 1970.
- [6] Antonina V. Nikulina, Vladimir A. Markelov, Mikhail M. Peregud, Yury K. Bibilashvili, Vladimir A. Kotrekhov, Anatoly F. Lositsky, Nikolay V. Kuzmenko, Yuriy P. Shevnin, Valentin K. Shamardin, Gennady P. Koylyansky, Andrey E. Novoselov, "Zirconium Alloy E635 as a Material for Fuel Rod Cladding and Other Components of VVER and RBMK Cores", Proceedings of the 11<sup>th</sup> International Symposium on Zirconium in the Nuclear Industry, ASTM STP 1295, p785.